Preface

The steady march of radio receiver technology over the decades has enabled smaller and increasingly capable radio terminals. The development of the transistor in the 1950s enabled the replacement of heavy tubes, which reduced receiver weight dramatically. To take advantage of the lighter transistor, engineers in the second half of the twentieth century engaged in a sustained effort to replace each analog component of the radio with a digital component. For example, the analog phase-locked loop comprising a linear multiplier, voltage-controlled oscillator, and resistor capacitor (RC) loop filter was replaced by a digital phase-locked loop comprising a digital multiplier, numerically controlled oscillator, and digitally implemented filter. Over the years, the digital domain was pushed further and further toward the front end of the receiver, until eventually the all-digital receiver was born in the 1990s. This receiver converts the intermediate frequency signal directly to digital samples, with all processing thereafter accomplished digitally.

With all operations done digitally, radios began to become more flexible as well, because loop bandwidths, gains, data rates, etc., were easier to adjust in the digital domain. This increasingly capable reconfigurable radio evolved into what is now called a software-defined radio (SDR), or cognitve radio, in which nearly all aspects of the radio are redefinable. A premier example of an SDR is the National Aeronautic and Space Administration (NASA) Electra radio, in which the baseband processing is entirely implemented in a reconfigurable field programmable gate array (FPGA). Virtually any channel code, modulation, and data rate may be accommodated via suitable reprogramming of this SDR.

The purpose of this monograph, and the natural next step in the evolution of radio receiver technology, is the development of techniques to *autonomously* configure an all-digital SDR receiver for whatever type of signal happens to hit its antenna. We describe automatic identification of the carrier frequency, modulation index, data rate, modulation type, and pulse shape, based on observations of the received signal. These are functions that typically are configured manually by the user of an SDR, prior to reception, based on a priori knowledge. We also describe how the conventional receiver estimators for the signal-to-noise ratio, carrier phase, and symbol timing require knowledge of the modulation type, data rate, and so on, and we show how these conventional functions can be implemented in the absence of this information.

For each of the estimators described above, we develop the optimal solution using a maximum-likelihood (ML) approach, and we offer simplifications and low-complexity approximations. When the solutions are highly complex or intractable, we present ad hoc estimators. Finally, we show how the suite of estimators may be combined into a working radio receiver.

Although the title of this monograph indicates that the autonomous radio technology described herein is for deep-space applications—and it certainly applies there, for auto-configuration of both Deep Space Network (DSN) and situ relay radio receivers—the development here is actually quite general. Indeed, virtually any terrestrial radio with the capability to process more than one type of signal can take advantage of the theoretical development and algorithms presented in the monograph.

Jon Hamkins and Marvin K. Simon
Editors
2006